Plant Gene Expression Center

Biotechnology for Agriculture

U.S. Department of Agriculture
Agricultural Research Service

University of California at Berkeley

California Agricultural
Experiment Station

Introduction

Each stage in a plant's life is controlled by its genes. At the Plant Gene Expression Center in Albany, California, our research provides new, precise information on exactly how these genes are expressed—turned on or turned off. Center scientists and colleagues worldwide can use this knowledge to find and improve genes that control agriculturally important traits, such as resistance to disease, or the ability to more efficiently convert sunlight into food.

Our discoveries will change the way plants are grown for both food and nonfood products, boosting their value to growers, processors and consumers alike. Our advances benefit all growers, from the commercial farmer to the home gardener. Here is a brief introduction to our investigations and achievements.

A postdoctoral associate discusses the structure of phytochrome—plants' light sensors—with Dr. P. H. Quail (right), molecular photobiologist and Director of Research.

How Plants Tell Day From Night: Phytochrome

Inside every green plant, molecules called phytochrome sense dark and light and send signals that start or stop plant activities. Phytochrome turns on genes that cause seeds to sprout and plants to grow. Agricultural Research Service scientists discovered phytochrome some 40 years ago. Today, we are using biotechnological tools to build new phytochrome genes for plants of the future.

We are scrutinizing not only the phytochrome molecule itself but also the genes that produce it and the genes it influences. We have shown, for the first time, that at least three different genes are involved in directing a plant to make phytochrome. This coordinated effort by a family of genes perhaps explains how phytochrome affects so many diverse events in a plant's life.

Bruce, W.B., Deng, X.-W. and Quail, P.H. 1991. A negatively acting DNA sequence element mediates phytochrome-directed repression of *phyA* gene transcription. *EMBO J.* 10:3015-3024.

Dehesh, K., Bruce, W.B. and Quail, P.H. 1990. A trans-acting factor that binds to a GT-motif in a phytochrome gene promoter. *Science* 250:1397-1399.

Bringing Speed, Precision, to Gene Engineering

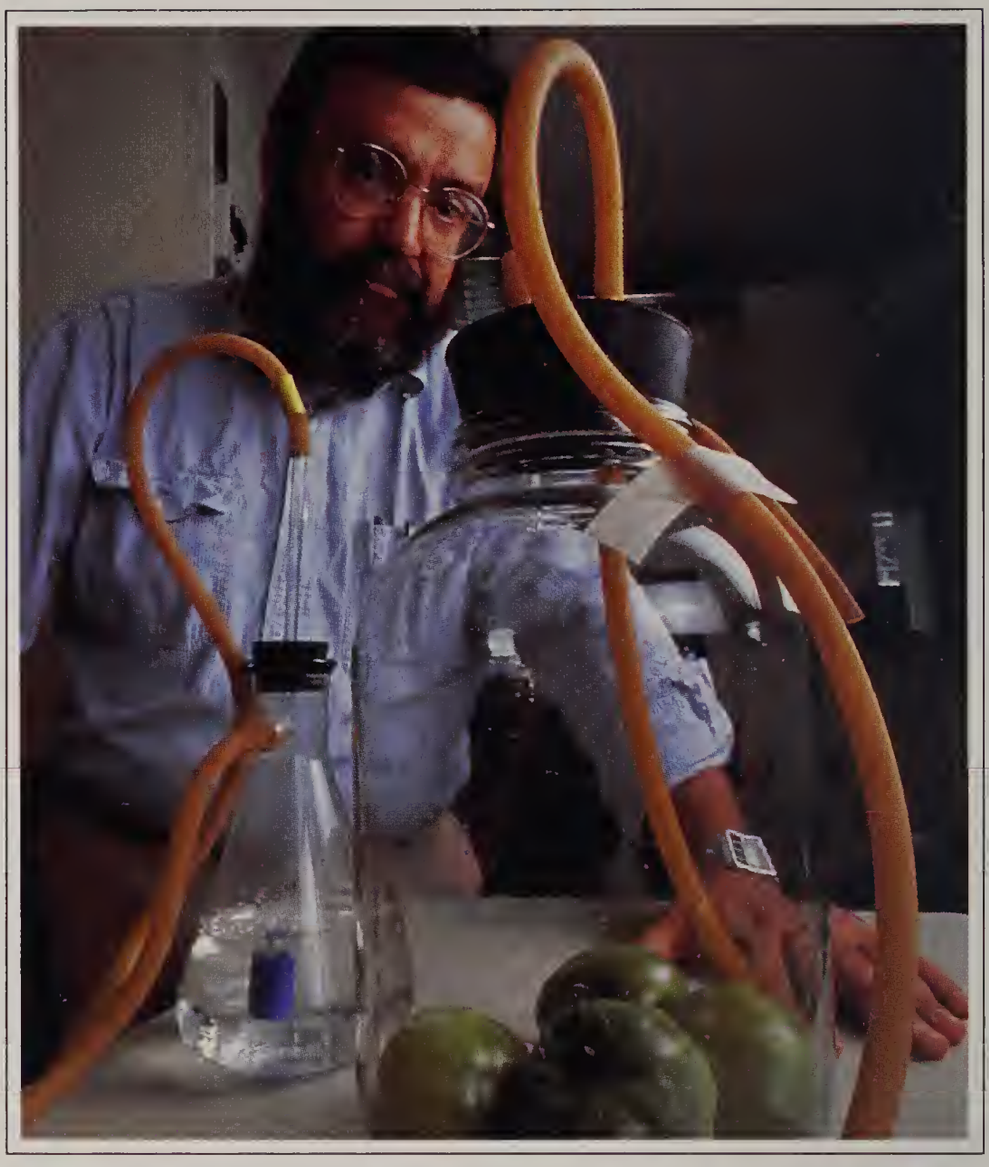
Rearranging a plant's genetic makeup by giving it new, useful genes or by taking out unwanted ones is an evolving art and science. We are honing a technique that allows biotechnologists to insert genes with new speed and precision. Our approach, for instance, permits easy removal of marker or reporter genes—ones vital to early stages of laboratory or greenhouse experiments but later unneeded. This editing option will simplify regulatory approval of gene-engineered foods such as tomatoes by reducing the number of new genes that must be reviewed. We can likely broaden the technique to cut, move, and attach whole segments of genetic material, speeding the transfer from one plant to another of all the useful genes located on the segment. In related work, we are probing the largely unexploited ability of what are known as plant RNA viruses to safely shuttle useful genes into plants.

We may use some or all of these technologies to build crops that can thrive on soils contaminated with heavy metals like cadmium or mercury. We want to study and redesign genes responsible for the activity of phytochelatins—natural compounds in plants that bind to these metals. The modified genes might, for instance, instruct phytochelatins to harmlessly store metals in portions of the plant that we don't eat.

Dale, E.C. and Ow, D.W. 1991. Gene transfer with subsequent removal of the selection gene from the host genome. *Proc. Natl. Acad. Sci. USA* 88:10558-10562.

Ortiz, D.F., Kreppel, L., Speiser, D.M., Scheel, G., McDonald, G., Ow, D.W. Heavy metal tolerance in the fission yeast requires an ATP-binding cassette-type vacuolar membrane transporter. *EMBO J.* (in press).

Molecular biologist Dr. D.W. Ow (left) and his postdoctoral associate examine colonies of metal-binding yeasts, miniature models for green plants.



Gene-engineered tomatoes ripen when Dr. A. Theologis, molecular biologist, applies ethylene.

Rewiring Plant Hormones

How plants develop and mature is dictated, in part, by their hormones. Our findings about two important hormones—auxin and ethylene—may enable us to control plants' growth and maturity in useful new ways. We could speed plant growth, for example, if we were able to stimulate genes controlled by auxin. In our experiments, we determined the structure of three auxin-controlled genes and explored their activity in peas, corn, and other plants.

Ethylene is essential for ripening. We found a gene critical to production of ethylene and reversed its message, blocking nearly all of the natural ethylene output from experimental tomatoes. When later exposed to externally applied ethylene, the tomatoes ripened normally. In the future, growers or shippers might use this technology to ripen many other fruits and vegetables, or cut flowers, enhancing freshness and reducing spoilage losses and refrigeration costs.

Oeller, P.W., Wong, L.M., Taylor, L.P., Pike, D.A. and Theologis, A. 1991. Reversible inhibition of tomato fruit senescence by antisense 1-aminocyclopropane-1-carboxylate synthase RNA. *Science* 254:437-439.

Sato, T. and Theologis, A. 1989. Cloning the mRNA encoding 1-aminocyclopropane-1-carboxylate synthase, the key enzyme for ethylene biosynthesis in plants. *Proc. Natl. Acad. Sci. USA* 86:6621-25.

Sex, Flowers, and Pollen

From apples to zucchini, most foods originate from plants' fertilized flowers. We could improve our harvests by studying how plant genes function during flowering. In tomatoes, we discovered several genes that act within a flower's anthers, the place where pollen is produced. We also identified certain promoters, that is, regions of genes that act as on-off switches. We are now pinpointing the role of proteins produced by pollen genes, such as those that cue a grain of tomato pollen to fertilize the female part of a tomato flower.

Some plants have genes that render their anthers infertile. In certain cases, this male sterility is desirable: it allows plant breeders to fertilize male-sterile plants with pollen from specially selected sources. We are isolating male-sterile genes and intend to place them under the control of a promoter that we can turn on or off at will.

McCormick, S. 1991. Molecular analysis of male gametogenesis in plants. *Trends in Genetics* 7:298-303.

Twell, D., Yamaguchi, J., Wing, R.A., Ushiba, J., and McCormick, S. 1991. Promoter analysis of genes that are coordinately expressed during pollen development reveal pollen-specific enhancer sequences and shared regulatory elements. *Genes and Development* 5:496-507.

Dr. S. M. McCormick, research geneticist (right), and her postdoctoral associate analyze the genetic code of a tomato pollen gene.

Dr. S. C. Hake, research geneticist, inspects experimental corn for signs of genetic change.

Discovering the Master Genes

As a plant grows, its cells change and help form structures such as leaves or fruits. Genes orchestrate these changes, but we don't know which genes—or how they work. If we did, we could improve tomorrow's plants.

To uncover key genes, we rely on transposons—pieces of genetic material that lock onto genes and interfere with their normal workings. When the resulting plants differ from their counterparts, we learn the role of the gene the transposon altered. The transposon has essentially found that gene for us. That is how we isolated a gene in corn plants, *Knotted*, that plays a role in forming normal leaves, free of knots or lumps.

What's more, we discovered that *Knotted* contains a homeobox, a master circuit that controls many other genes. The finding, a first for plants, has simplified our search for other genes that *Knotted* directs and has helped us turn up new homeoboxes in other plants.

Veit, B., Greene, B., Lowe, B., Mathern, J., Sinha, N., Vollbrecht, E., Walko, R. and Hake, S. 1991. Genetic approaches to inflorescence and leaf development in maize. *Development, Supp.* 1:105-111.

Vollbrecht, E., Veit, B., Sinha, N., and Hake, S. 1991. The developmental gene *Knotted* is a member of a maize homeobox gene family. *Nature* 350:241-243.

Transposons—Nature's Agents of Change

Some plants shrug off attacks by viruses, bacteria, or fungi. We know that single genes, working alone, give certain plants resistance. Our long-term research goal is to isolate these resistance genes, solve the puzzle of how they work, and insert them into plants that lack inherent protection. One target is the gene that protects tomato plants from wilt, a disease caused by a soil-dwelling fungus. We also seek a gene that confers resistance to tobacco mosaic virus disease, caused by a virus that damages tomato as well as tobacco.

To sleuth these genes, we use genetic material called transposons. In the process, we are refining our earlier pioneering work to expand transposons' capabilities.

We envision using these improved transposons, for example, to perform such tasks as inserting genes for disease resistance or other useful traits, or for deleting unwanted genes. Our experiments focus on two well-known transposons from corn, *Activator* and *Dissociation*. With further work, these transposons will offer a quick, exact, and powerful way to find and rebuild genes not only in corn but other plants as well, including tomato and rice.

Baker, B., Fedoroff, N., Loerz, H., and Schell, J. 1986. Transposition of the maize controlling element *Activator* in tobacco. *Proc. Natl. Acad. Sci. USA* 83:4844-4848.

Hehl, R. and Baker, B. 1990. Properties of the maize controlling element *Activator* in transgenic tobacco plants: a versatile interspecies genetic tool. *Plant Cell* 2:709-721.

Dr. B. J. Baker, research geneticist, employs transposons to hunt key genes in rice plants.

How to Work with Us

We invite research collaborations under the auspices of the Center's consortium. Our success in genetically engineering corn is one example of a team project by Center, corporate, and university scientists. Similar corporate-sponsored research now targets other grain crops. Proposals for collaborative research and technology transfer should be sent to the Center Director (see address below).

The Center offers a fast-paced, challenging research environment that fosters innovation and demands high productivity. Our permanent staff of principal investigators and support scientists is assisted by undergraduate and graduate students from the nearby University of California at Berkeley, and postdoctoral students from the United States and abroad.

For information on employment opportunities, send your resume, including any publications, and a description of your research interest to ***Dr. Gerald G. Still, Director, UC/USDA Agricultural Research Service Plant Gene Expression Center, 800 Buchanan St., Albany, CA 94710. Phone: (510) 559-5900. FAX: (510) 559-5678.***

The U.S. Department of Agriculture and University of California are equal opportunity employers.

Established in 1984, the Center is a joint venture of the U.S. Department of Agriculture's Agricultural Research Service; the University of California at Berkeley; and the California Agricultural Experiment Station.

Cover: *Dr. A. Theologis reads a sequence gel to decode the genetic makeup of a tomato plant.*

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